NATIONAL STATUS AND TRENDS PROGRAM FOR MARINE ENVIRONMENTAL QUALITY:

TOXIC CONTAMINANTS IN LONG ISLAND SOUND

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ABOUT THIS REPORT

This report summarizes results of the National Status and Trends (NS&T) Program from Long Island Sound. It characterizes the system, its drainage basin, and inputs that influence the concentrations of contaminants and biological responses to those substances. These results are shown in relation to those obtained at all other NS&T sites around the United States. This summary provides information to help local and state resource managers evaluate toxic contaminant conditions in their areas and place those conditions in perspective to those throughout the Sound and across the nation.

NATIONAL STATUS AND TRENDS PROGRAM

In response to the need for information assessing the effects of human activities on environmental quality in coastal and estuarine areas, and the need to develop management strategies to deal with these conditions, the Ocean Assessments Division of the National Oceanic and Atmospheric Administration (NOAA) initiated, in 1984, the National Status and Trends Program (NS&T). The purpose of this program is to determine the current status and detect changes that are occurring in the environmental quality of our nations's estuarine and coastal waters. Because of concern over inputs of contaminants to U.S. coastal waters, it was decided to focus the program initially on these substances and their effects. The NS&T Program has three major components: the **Benthic Surveillance Project**; the **Mussel Watch Project**; and **Historical Trends Assessment**. These components are organized in a three-tier structure which provides for cost-effective collection of data.

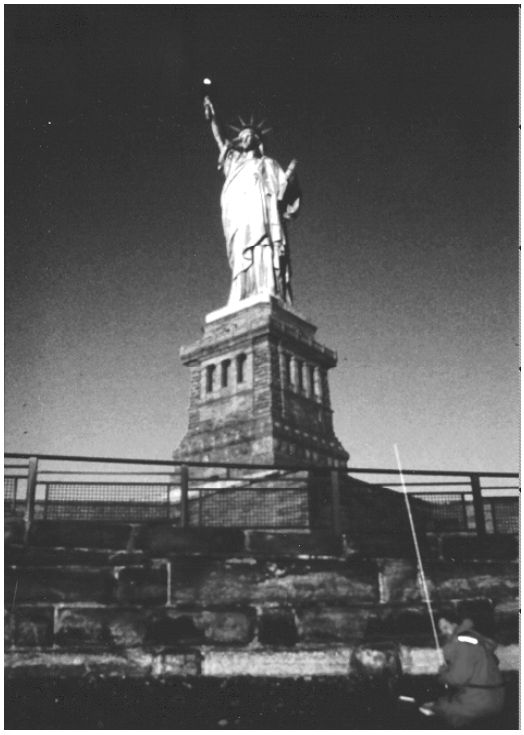
The first tier, **Nationwide Monitoring**, measures the levels of contaminants and certain associated effects in biota and sediments. It provides data for making spatial and temporal comparisons of contaminant levels to determine which regions around our coasts are of greatest concern regarding existing or developing potential for environmental degradation. It includes measurements of concentrations of 24 polycyclic aromatic hydrocarbons, 18 congeners of polychlorinated biphenyls (PCBs), DDT and its breakdown products (DDD and DDE) and 9 other chlorinated pesticides, butyltins, and 12 toxic trace elements in sediments, mussels, and oysters at a network of about 200 regionally representative sites by the **Mussel Watch Project.** Additionally, determinations of the levels and effects of the same chemicals in the livers of bottom-dwelling fish and associated sediments are made by the **Benthic Surveillance Project** at about 75 sites. The frequency of external disease and internal tumors are documented in the fish studied. Data from all monitored sites are stored on NOAA national databases, analyzed, and made available to estuarine managers and to the public in a variety of reports (over 100 to date).

Sampling and analyses for the NS&T monitoring projects are performed using well-documented methods and techniques, so that a known level of confidence can be assigned to all data. Analytical procedures adhere to the standard procedures of the NOAA Quality Assurance Program, established for all laboratories participating in the NS&T Program. Selected samples collected as part of the activities of the NS&T Program are preserved in liquid nitrogen and stored at -150° C. A specimen archive of these samples has been established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) in Gaithersburg, MD. Specimens from the archive will be available for retrospective analyses as new analytical techniques become available and perceptions of environmental quality issues change.

The second tier, **Historical Trends Assessment,** involves a closer examination of the environmental conditions in the regions that were indicated by the first tier as having the highest levels of specific contaminants and likewise the greatest potential for environmental quality problems. This tier synthesizes the available data and information pertaining to the status and trends of toxic contaminants and their effects in regions of concern to assess the present state of knowledge on the magnitude and extent of degradation to living resources and their habitat.

The third tier, **Biological Effects**, consists of a series of intensive two- to three-year studies focused specifically on those regions where NS&T analyses indicated a potential for substantial environmental degradation and the need for further information. Most studies are conducted by **Benthic Surveillance Project** scientists, and focus on living marine resources, especially bottom-dwelling fish. Studies are done on such subjects as reproductive impairment, genetic damage, sediment toxicity, refinement of methodologies, and evaluation of new indicators of contamination (DNA damage and enzymatic activity in fish livers), as well as on contaminant concentration gradients in the biota.

TOXIC CONTAMINANTS IN LONG ISLAND SOUND



Collecting mussels at one of the 200 Mussel Watch sites

GENERAL DESCRIPTION

The following information on the characteristics of Long Island Sound and the land use within its drainage system is important to interpreting NS&T contamination measurements.

•Long Island Sound, an elongate embayment with a predominantly east-west axis, is 199 miles in length and averages 12 miles in width. It has a water surface of 1,268 square miles, a volume of 2.19 trillion cubic feet, an average depth of 62 feet, and a total shoreline of 1,004 miles (EPA/NOAA Team, 1987). It ranks 6th in estuarine surface area and third in estuarine water volume among U.S. estuaries (Donovan and Tolson, 1987).

•The Sound has a total land drainage area of 15,696 square miles, ranking it 19th in drainage size among U.S. estuaries. About 11,100 square miles (70.7%) of this total is in the drainage of the Connecticut River (Strategic Assessment Branch, 1985).

•The Sound's estuarine drainage area (the land and water component of the entire watershed that most directly affects the Sound) occupies 6,954 square miles. The most recent (1975) land-use data for this drainage area indicate that 1,418 square miles were urban, 842 square miles were agricultural, 52 square miles were rangeland, 33,142 square miles were forested, and 250 square miles were in other land-use categories (wetlands), and the remainder was water surface (EPA/NOAA, 1987).

•The Sound is a vertically homogenous estuary. Its seawater mixes thoroughly with lower salinity water at the western end and at the mouths of the major rivers in mixing zones which comprise 7% of the total estuarine volume. A semidiurnal tide prevails (two high and two low tides daily). At the mouth of the Sound (the Race), the tidal range is 2 feet (EPA/NOAA Team, 1987).

•The Sound ranks 4th in population (5.74 million) and 10th in population density (1,008 people per square mile) among U. S. estuarine drainage areas (Donovan and Tolson, 1987).

•For 1985, the total recreational fish catch in the Sound was 35.6 million pounds, predominantly (by poundage) bluefish, scup, winter flounder, summer flounder, tautog, and weakfish. The commercial catch, for 14 principle species was 7 million pounds of finfish and shellfish. These were, in order, American lobster, eastern oyster, quahog, winter flounder, bluefish, and long-finned squid (Smith et al., 1989).

•Of the 859,000 acres of molluscan shellfishing waters in the Sound in 1985, about 718,000 acres (83.6%) were classified approved for harvest, 135,000 acres (15.7%) were prohibited, and 6,000 acres (0.7%) were conditionally approved; closed when standards are not met, usually after a rainfall (Leonard et al., 1989).

•Approximately 88 miles of estuarine channels are dredged annually, with dredged material deposited onto spoil banks covering 12 square miles (Orlando

LONG ISLAND SOUND STUDY

The NS&T activities in the Sound are being carried out in close cooperation with the Long Island Sound Study (LISS), sponsored by the U.S. Environmental Protection Agency (EPA). LISS is a six-year project to identify the major environmental problems in the Sound and to develop a comprehensive management plan by 1991 to recommend ways to solve them. The results of the NS&T work are being integrated with results from LISS concerning toxics to develop the toxic contamination section of the management plan.

Long Island Sound is designated as an estuary of national significance in EPA's National Estuary Program (NEP). NEP provides assistance to nationally significant estuaries that are threatened by pollution, development, or overuse.

LONG ISLAND SOUND NS&T

In Long Island Sound, the NS&T Program has sampled, since 1984, winter flounder (Pseudopleuronectes americanus) and surface sediments for more than 50 toxic chemicals at two **Benthic Surveillance** sites (indicated as sites 10-11 on Figure 1). Also, NS&T's **Mussel Watch** has sampled, since 1986, the blue mussel (Mytilus edulis) and sediments for the same contaminants at nine sites (indicated as sites 1-9 on Figure 1). These sites were carefully selected to represent general contamination conditions in the Sound, and were not located in or near "hot spots", discharge pipes, or other localized dumpsites. The Sound's **Benthic Surveillance** samples are collected and analyzed by the Northwest Fisheries Center, National Marine Fisheries Service under cooperative agreement with the Ocean Assessment Division, National Ocean Service. **Mussel Watch** samples are collected and analyzed by Battelle Ocean Sciences.

An NS&T Tier III study was conducted by the Northwest Fisheries Center at four sites in the Sound (Site 10 and three additional sites indicated on Figure 1 by triangle designators). Samples of sediment, infaunal invertebrates, and winter flounder were collected to

evaluate the degree of chemical contamination and determine possible effects of exposure. The site near New Haven, CT, (Morris Cove) was chosen to test for biological responses under extreme conditions. It had the highest levels of chemical contamination in sediment and tissues, generally the highest prevalences of histological changes and DNA alterations in winter flounder, and the lowest abundance and species richness of infaunal invertebrates. Neither it nor any of the other Sound sites sampled had either contaminant levels or prevalences of contaminant-related disease conditions (lesions) in fish livers that approached the worst conditions found nationally at NS&T locations. Another Tier III study was done on blue mussels from Nantucket, MA, held in cages in sites near the mouths of the Quinnipiac, Connecticut, Housatonic, and Thames Rivers. After 1.5 months, significant uptakes of trace metals, pesticides, and PCBs were noted. Arsenic and cadmium were high in mussels from the Housatonic River (Phillips et al., 1987).

Two Tier III studies are underway on the reproductive success of winter flounder. One will compare the severity of contaminant effects on ovarian maturation of winter flounder from the Sound with those from Boston Harbor; the other will compare the viability of eggs taken from fish in various locales within the Sound with egg viability from Boston Harbor. Three other Tier III studies are being conducted in the Sound: (1) an examination of sediment toxicity from where the Housatonic River enters the Sound to the New York-New Jersey Harbor; (2) a study of the reproductive success in lobsters in waters that are taken from areas with different levels of pollution; and (3) an examination of the possibility that the high levels of selected trace metals (especially copper and zinc) that are found in more contaminated waters of the Sound are toxic to sensitive test species.

NS&T DATA

The graphs on the next four pages show the NS&T results from Long Island Sound for the toxic contaminants of greatest concern compared to the nationwide results for these contaminants. Concentrations of contaminants in sediments, mussels, and fish at the Sound sites are indicated by the heights of the solid lines (concentrations are on a logarithmic scale). Numbers at the top of each graph refer to the site locations in Figure 1. The curves, based on mean concentrations for all NS&T sites, describe the nationwide distribution of concentrations. The curves for mussels were derived from the means of three years of results from mussel tissues. The fish data are 2-year means of results from the livers of all fish species, while the sediment data are 2-year means. Also noted is the number of sites (n) used to form the

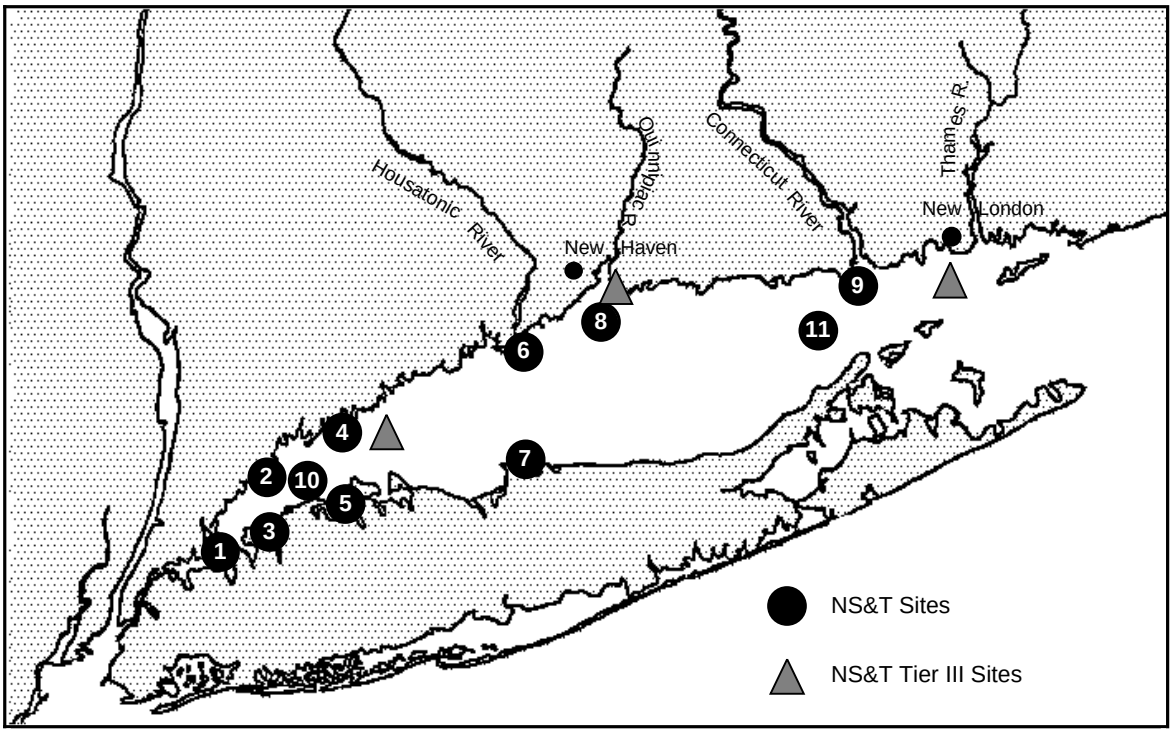


Figure 1. Long Island Sound NS&T monitoring sites and Tier III study sites.

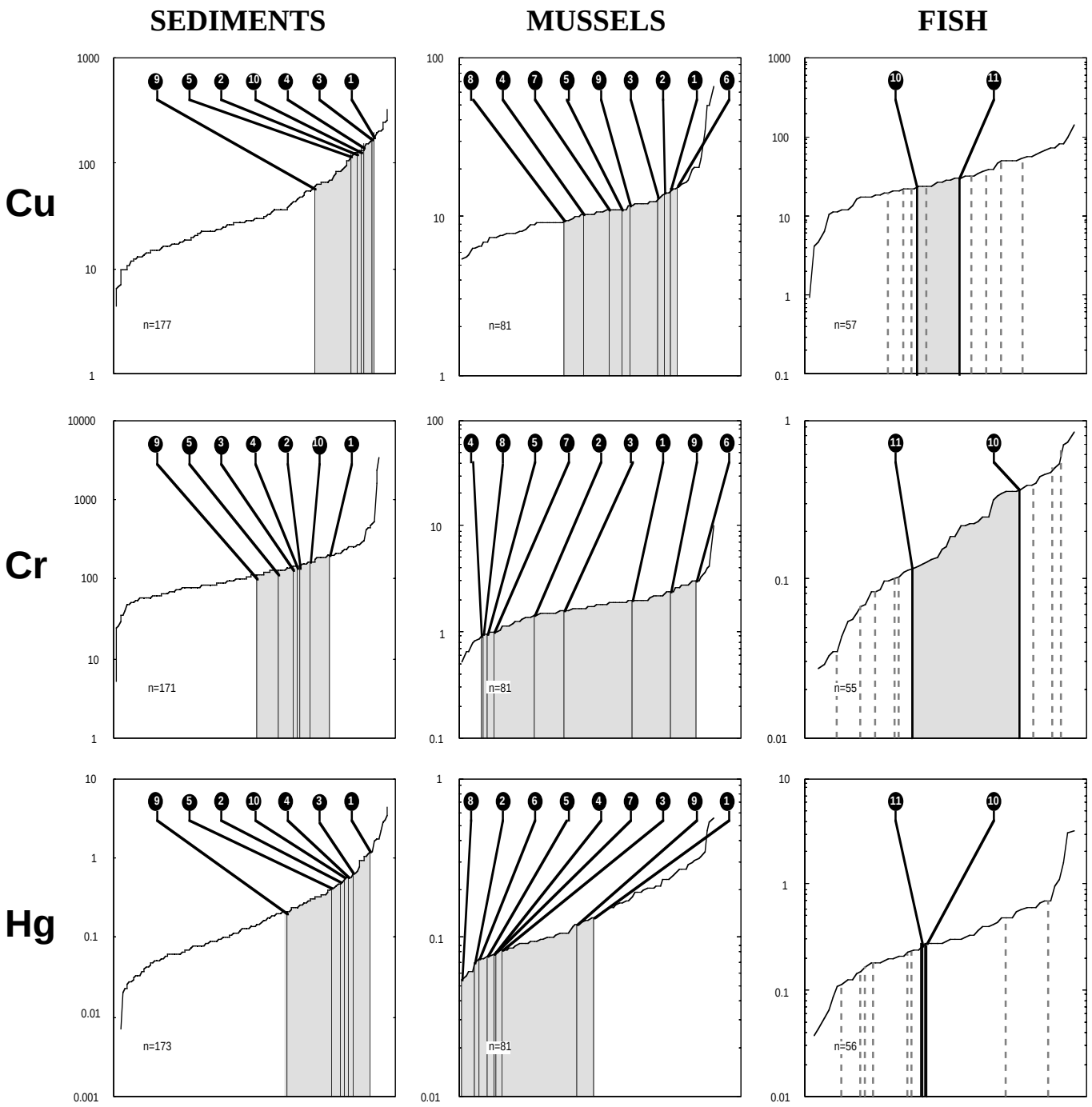


Figure 2. Distributions of six metals at Sound sites compared to national curves for sediments, mussel tissues and fish livers.

curve. All metal concentrations are in μg/g dry weight; all organics are expressed in ng/g dry weight. The shaded areas denote concentration ranges for Sound sites. Superimposed on the fish curves of both metals and organics are dotted lines denoting the concentrations found at other NS&T sites where concentrations in winter flounder liver were measured.

Results to Date: Toxic Metals

For all six metals, concentrations in the Sound's sediments tend to be moderately high on a national basis (Figure 2). The same is not true for the metal concentrations in mussels and fish, which tend to group near the centers of the national ranges. As sediment concentrations reflect contaminant levels over substantially longer time periods (a number of years) than the concentrations in biota (less than a

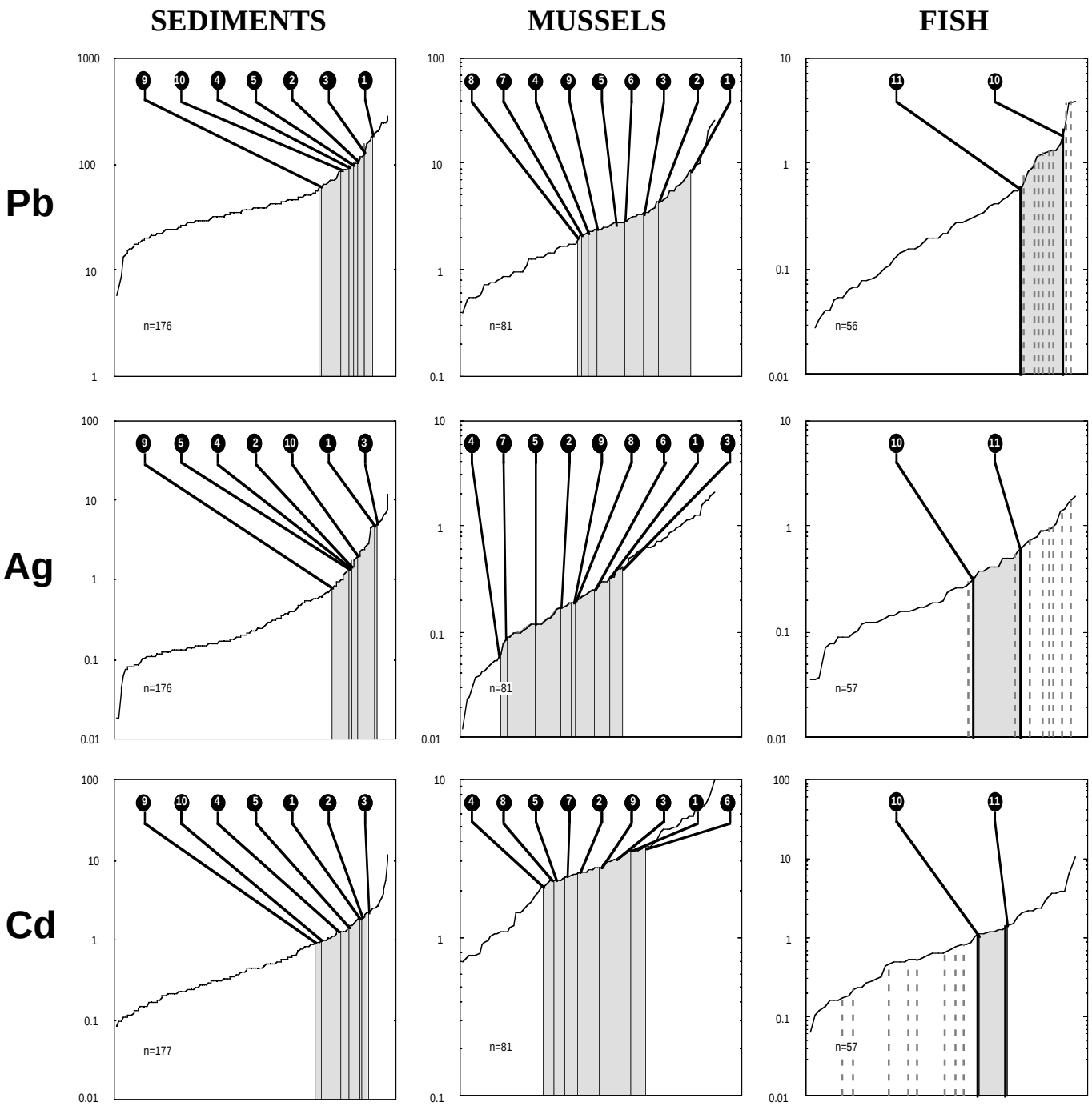


Figure 2. Continued.

year), this difference may indicate that Long Island Sound was relatively more contaminated with metals in relation to national levels in the past than is presently the case. This is not a surprising conclusion for an area that has been thickly populated and heavily industrialized longer than most around the United States. Lead, particularly in the sediments and fish livers, rather consistently shows natonal rankings nearer the maximum than do the other metals. This year, NS&T plans to investigate historical trends or inputs for toxic contaminants in estuaries of concern by examining sediment cores.

Within Long Island Sound, there is a strong tendency for the concentrations of metals, in both the sediments and the mussels, to be higher at the most westerly sites (sites 1-3) than further east. This is largely due to the relatively restricted dilution volume and flushing in this area coupled with high inputs of contaminants from the New York urban area. Mussels at site 6 at the mouth of the Housatonic River also show a tendency for higher metal levels than at

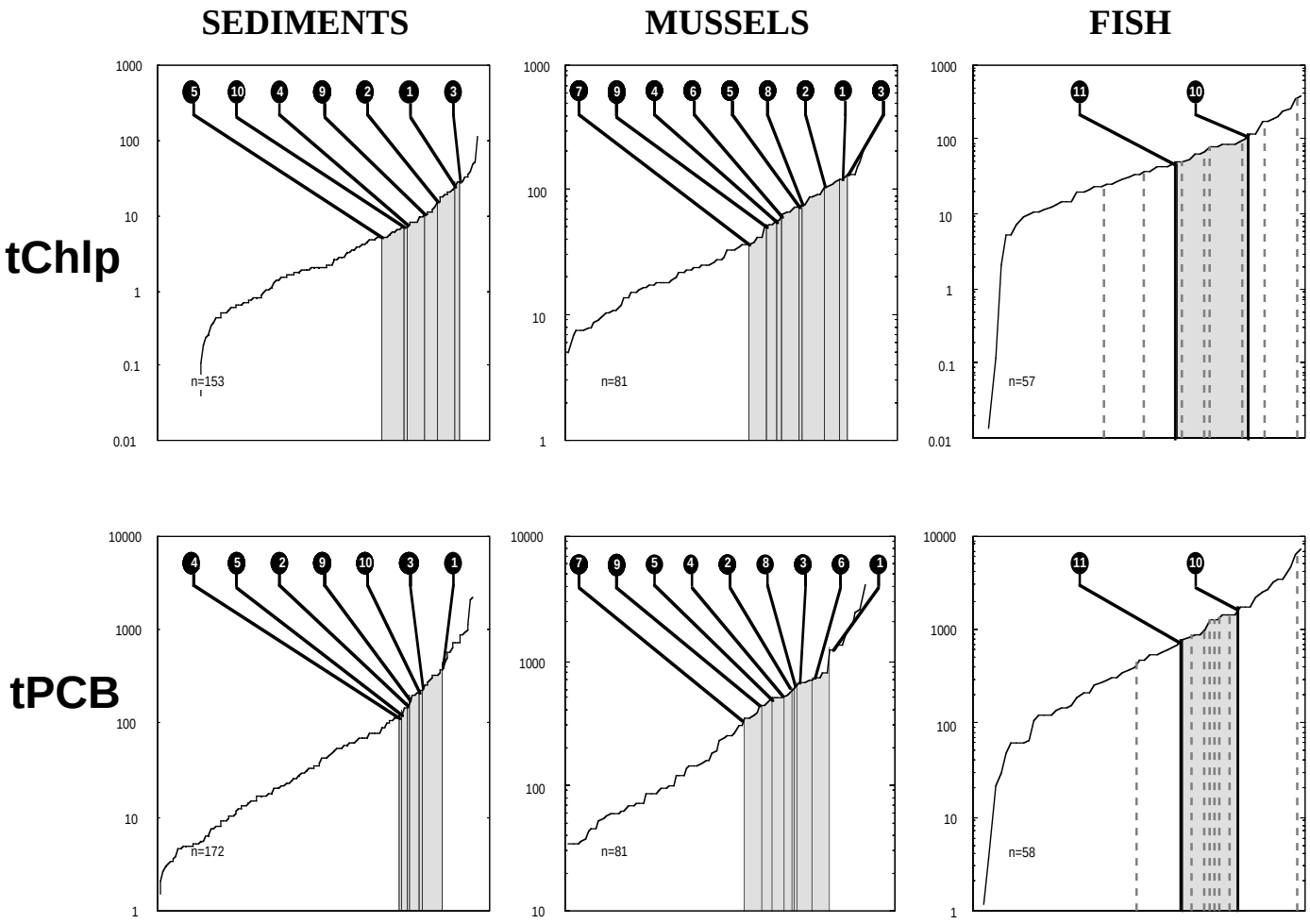


Figure 3. Concentrations of selected toxic organics at Sound sites compared to national curves for sediments, mussel tissues and fish livers.

most of the Sound sites.

Excluding the unknown contribution from the atmosphere, these metals enter the Sound primarily as dissolved and particulate constituents in the inflows of rivers, runoff directly from the land, and the effluents of wastewater treatment and industrial facilities. For copper, chromium, mercury, and cadmium, over 50% of the input to the Sound is mostly from industrial and municipal facilities along the major rivers upstream of the study area shown in Figure 3. Most of the remainder of the input for these metals is from the wastewater treatment plants in the study area. For lead, the situation is somewhat different in that runoff from urban areas, mostly related to the use of leaded gasoline, provides over one-third of the input, with upstream sources and wastewater treatment plants providing almost all of the remainder. Pollutant loadings are not available for silver in the Sound (input statistics are based on information circa 1982-84 provided by Farrow et al., 1986).

Results to Date: Toxic Organics

The levels of toxic organic compounds in Long Island Sound show distributional patterns that are quite similar to those of metals (Figure 3). As with the metals, the sediment concentrations of all toxic organics are found to be at moderately high levels when compared with the concentrations from the other sites in the national NS&T survey. Unlike metals, concentration values of total chlorinated pesticides (tChlps) and total polychlorinated biphenyls (tPCBs) tend to be higher in mussel tissue and fish livers than in sediments, as others have also demonstrated, due to these organic compounds being stored in organic, lipophilic tissues of the biota.

Within the Sound, the toxic organics generally show the same tendency observed with the metals; higher concentrations in both sediments and mussels at sites at the western end of the Sound near the New York metropolitan area (sites 1-3) than at the sites

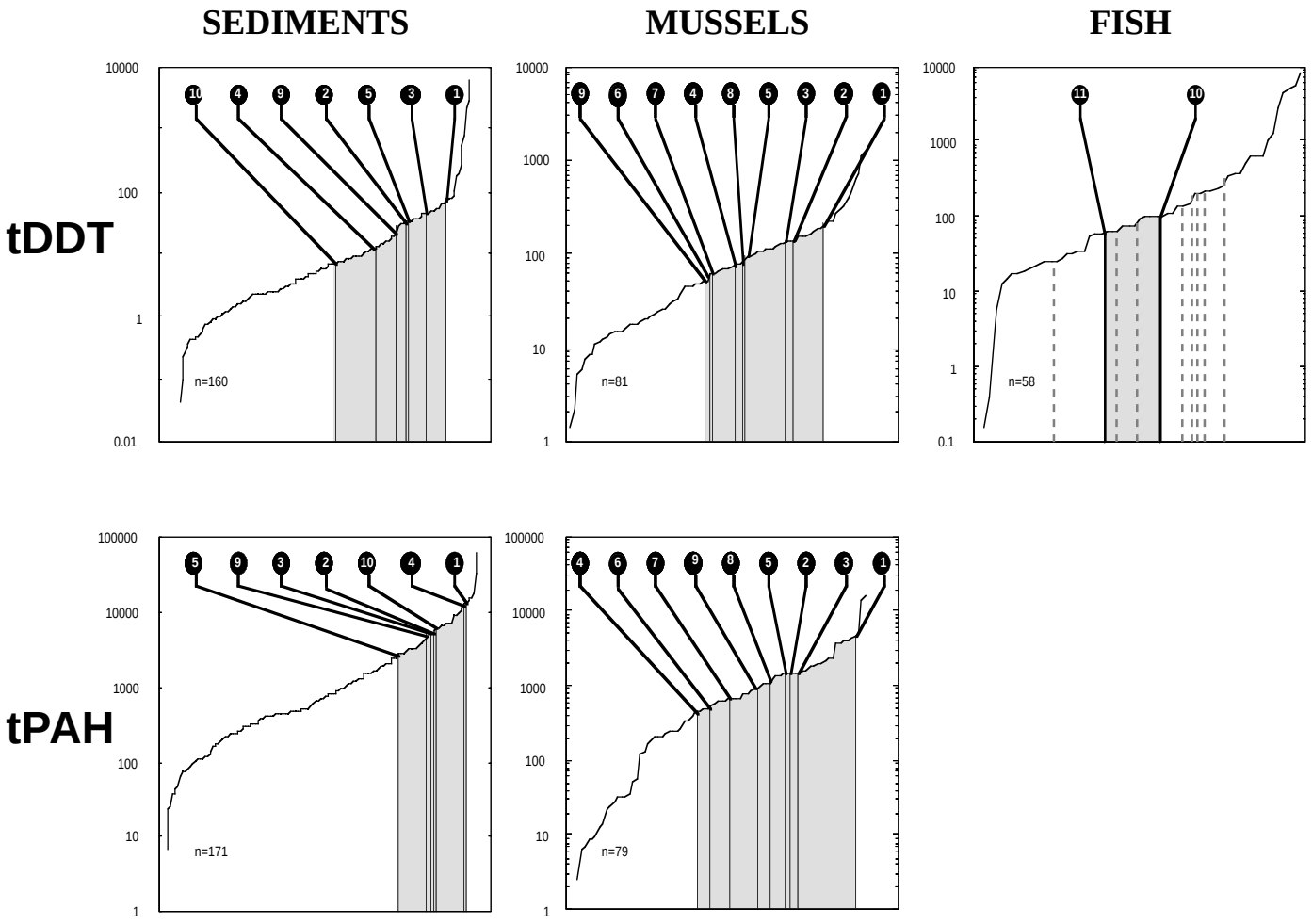


Figure 3. Continued.

further east. The values for toxic organics in mussels at site 8 near New Haven, CT, also tend to be higher than at the remaining stations (sediments were too sandy from site 8 for the data to be used).

Pollution Sources

Farrow et al. (1986) estimated the sources of pollutants to Long Island Sound from the area shown in Figure 4. This includes the entire Long Island Sound drainage area in New York State, but excludes the upstream portion of the drainage of nine rivers, and thus a major portion of the drainage area in Connecticut. The total upstream contribution to the Sound is the loading estimate for the nine rivers as they enter the study area. For most pollutants, the upstream loads provide more than half of the input to the Sound, with most of that from the Connecticut River, which accounts for 75% of the upstream flow.

Aside from these upstream contributions, wastewater treatment plants are the largest source for cadmium, copper, mercury, zinc, chlorinated hydrocarbon pesticides, and other contaminants (see Figure 4 for locations of major plants discharging more than 10 million gallons daily). Farrow et al. (1986) noted that as many as 86 wastewater treatment plants discharge into the designated study area. Four large New York City treatment plants that discharge to the Upper East River account for about 68% of the total municipal wastewater flow.

There are 24 major (>1 MGD) and 231 minor direct industrial discharge facilities, but they are not a major source of pollutants to the Sound. Even though they account for a substantial flow of water to the Sound, the 16 steam electric power plants with discharges containing corrosion products and biocides are also not a major contributor of contaminants.

Urban runoff is the second most important source after wastewater treatment plants for most pollutants. For lead, it is the most important source. Runoff from cropland and forestland tends to be minor sources for most of the toxic contaminants.

NATURAL VARIABILITY

Natural variation must be taken into account when interpreting data from monitoring studies. The NS&T established its network of sites generally to represent a site's contamination conditions in the areas sampled. There can, of course, be relatively restricted parts of these areas where contamination levels are much different than those found by the large-scale NS&T study. Such is known to be the case for several embayments, such as Black Rock Harbor, in Long Island Sound, where contamination levels are much higher than any found by NS&T sampling.

Seasonal and annual variations in environmental conditions can also affect the levels of contaminant detected. For example, variations in precipitation can have a marked influence on the inputs of contaminants. Large amounts of rain can decrease contaminant concentrations near mussel beds by diluting the inputs from point sources. On the other hand, such rains can increase concentrations though runoff associated with nonpoint sources. Storms also can have a marked effect on contaminant levels in coastal waters by exposing and resuspending sediments and thus causing increased exchange of contaminants with the ambient waters.

It is thought that seasonal changes in reproductive state and other properties of mussels can influence the levels of contaminants in their tissues. The NS&T Program tested the impact of seasonal variability on the levels of metals in mussels in the Sound. This study concluded that seasonal differences in these metals were small and would have little effect on the results of yearly trend analyses (Freitas et al., 1988). Nevertheless, samples are collected each year during the same season at the same sites. Additionally, measurements are made on factors that have been found, at times, to be related to contaminant levels such as lipid content and reproductive condition in biota and total organic carbon and particle size in the sediments. These measurements can be used to determine the influence of these factors and to normalize or otherwise account for their influence as necessary.

Repetitive monitoring over several years by the NS&T Program presents long-term, averaged information, thereby damping much of the extremes in variability. After five years, some indications of contaminant trends are emerging from the data.

CONCLUSIONS

Generally, the Nation's most contaminated estuaries are in highly urban areas, such as those around much of Long Island Sound. However, contamination in an estuary is the result of all discharges into the system modified by the system's capability to dilute, trans-

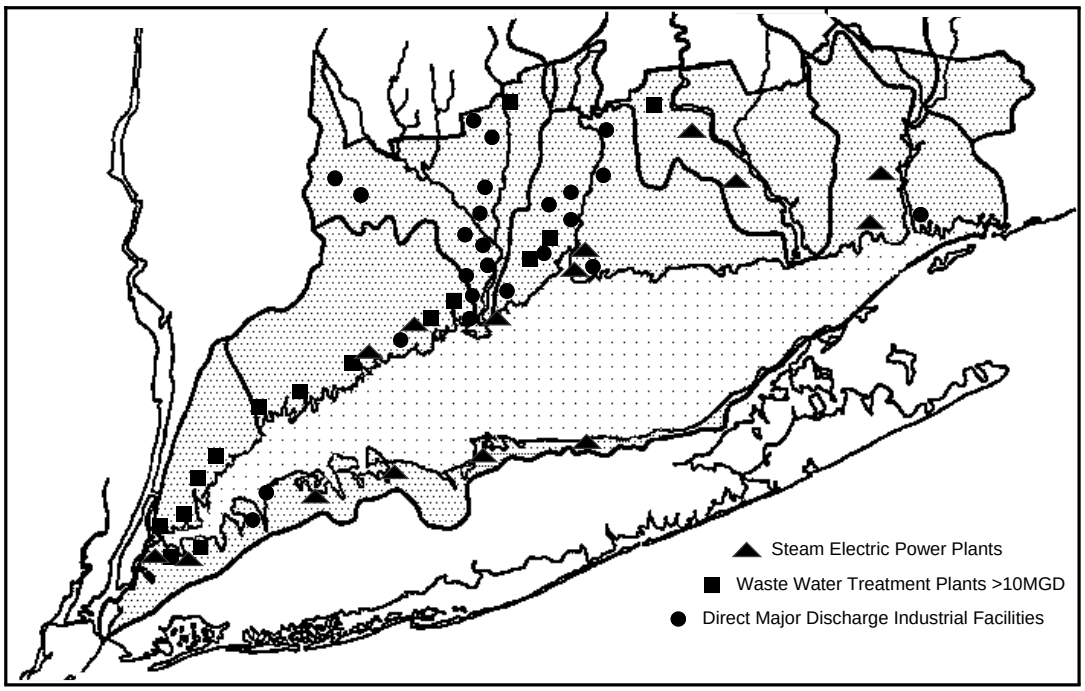


Figure 4. Sources of pollution in the study area (modified from Farrow et al., 1986).

form, and flush out to the open sea the contaminating substances. NOAA has developed a classification system for the relative susceptability of estuaries consisting of nine classes based upon "dissolved concentration potential" and "particle retention efficiency" (Klein et al., 1988). “Dissolved concentration potential” characterizes the effect of dilution and flushing on a per-unit-load of a dissolved and conservative pollutant to the estuary. “Particle retention efficiency” is the ability of an estuary to trap suspended sediment inputs and associated toxic substances. Using this system, Long Island Sound has a high particle retention efficiency and is highly susceptible to toxic accumulation problems in bottom sediments. However, with its large volume and efficient flushing characteristics, it is rated as having a low dissolved concentration potential and thus is less susceptable to contaminants which occur primarily in the dissolved phase. The toxic contaminants included in this paper, especially the organic compounds, tend to be strongly associated with particles and so are of particular concern with regard to their accumulation in the bottom sediments of the Sound and their effects on the invertebrates and fish that live and/or feed in close association with these sediments.

Looking at the results from the individual NS&T sites, five of the seven sites with fine-grained sediments in the Sound have concentrations for individual contaminants that place them among the 20 (out of 175) most contaminated nationwide for those contaminants. Table 1 shows the contaminant rankings for those sites in the Sound among the upper 20 nationwide. (This table includes information for tin (Sn) and zinc (Zn) which were not discussed in the earlier **Results to Date** section.) Throgs Neck (site 1) ranks in the top 20 nationally for all eleven contaminants, while the site at Hempstead Harbor (site 3) ranks in the top 20 for six of the contaminants. These results clearly illustrate that the more westerly sites, closest to New York, tend to have the highest concentrations of contaminants. They also show that, when compared nationally, many sites in the Sound are relatively highly contaminated for at least several contaminants.

SITE	Cu	Hg	Pb	Ag	Cd	Sn	Zn	tChlP	tPCB	tPAH	tDDT
1	9	11	10	11	18	20	20	12	16	7	13
2	19		19		16						
3	10		15	9	13		17	9			
4	15									8	
10	16					14					

Table 1. Long Island Sound Sites Ranked among the 20 Most Polluted NS&T Sites (based on 1984-87 means for fine-grained sedments at 175 nationwide sites).

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